NISTIR 6527

Measurement Needs for Fire Safety: Proceedings of an International Workshop

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U.S. Department of Commerce
William M. Daley, Secretary

Technology Administration
Dr. Cheryl L. Shavers, Under Secretary of Commerce for Technology

National Institute of Standards and Technology
Raymond G. Kammer, Director

FORUM WORKSHOP: Flow and Velocity Measurement Needs for Fire Safety

William Grosshandler
Building and Fire Research Laboratory

April 5, 2000

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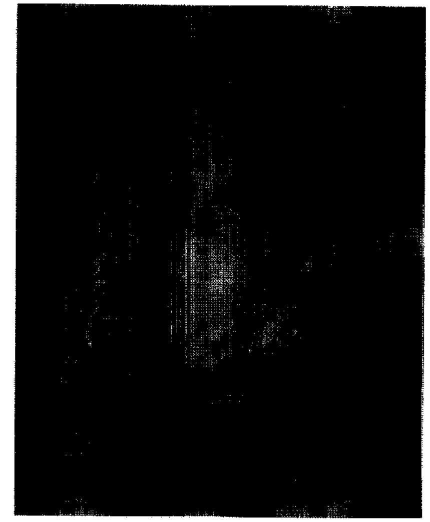
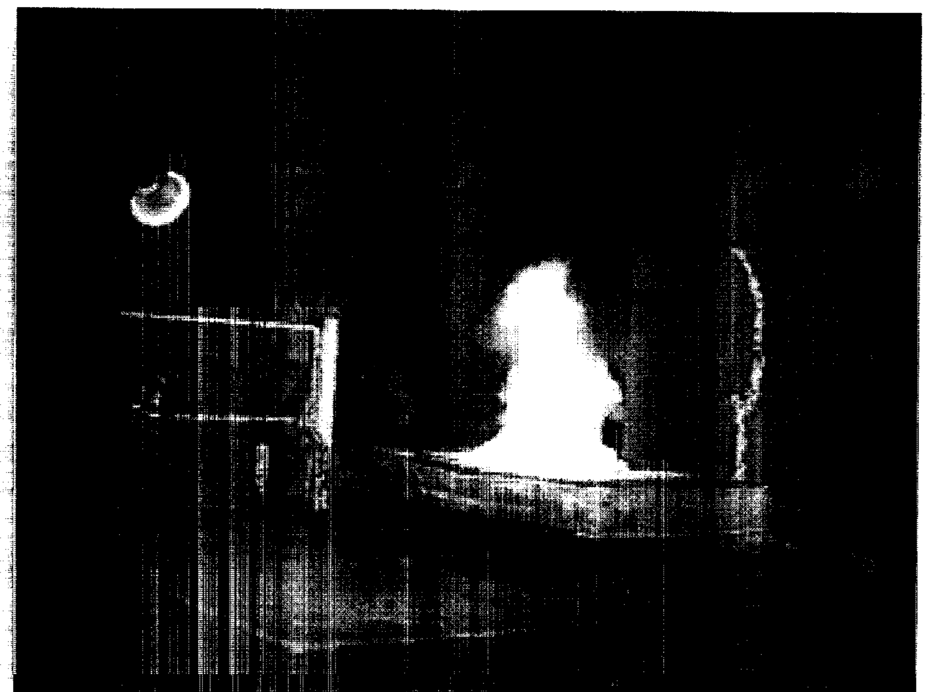
cone calorimeter



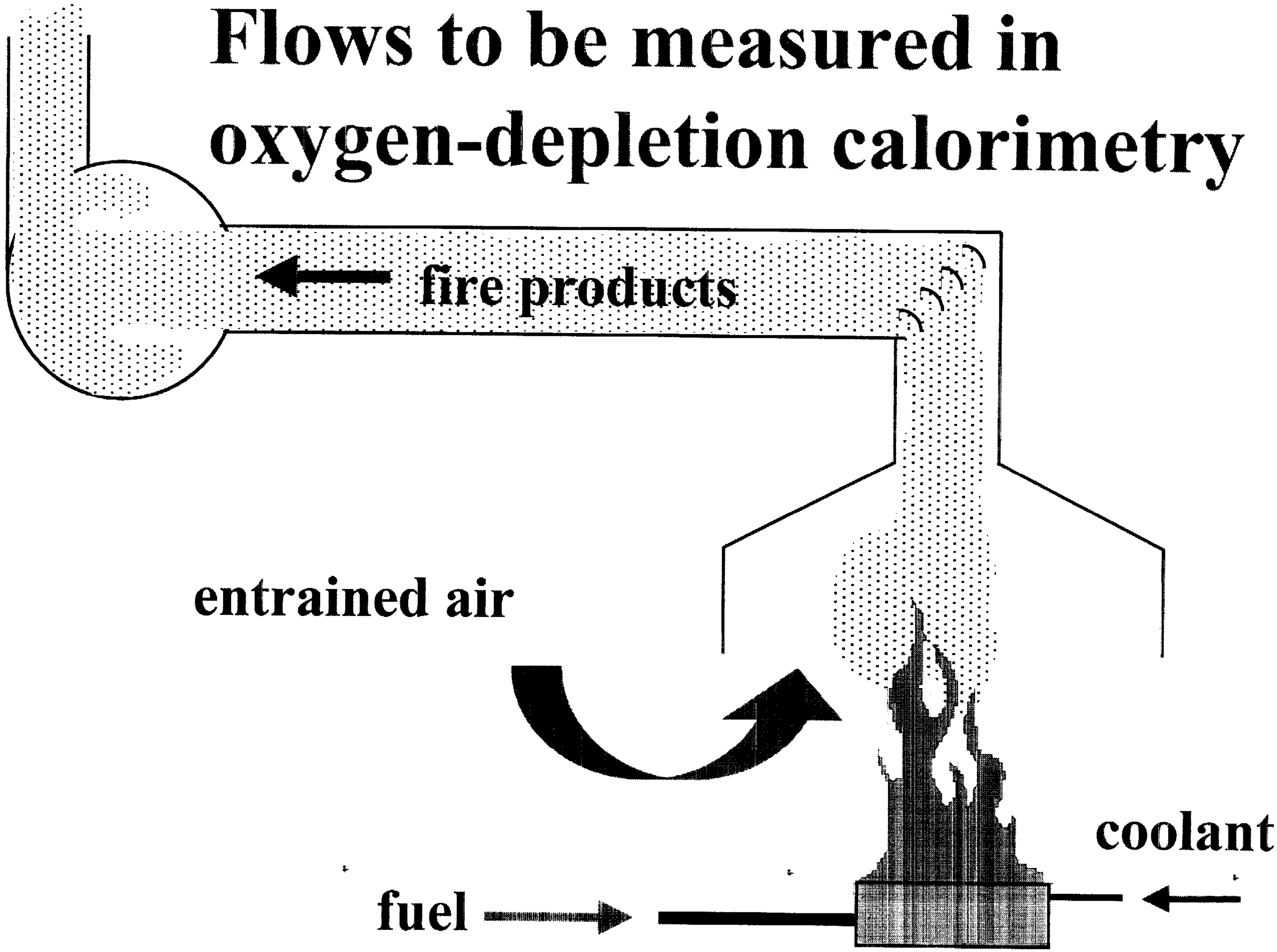
furniture calorimeter



room-scale calorimeter

Oxygen depletion calorimetry

Flows to be measured in oxygen-depletion calorimetry



Volume average devices

APPLI-CATION	MEASUREMENT METHOD	ADVANTAGES	LIMITATIONS
fuel (gas)	dry/wet test meter	high flow rate	accuracy, low pressure
	rotameter	flexible, inexpensive	cal. req.
	metering orifice	accurate, high flow rates, no cal., fast response	pressure drop
	electronic mass flow meter	electrical readout, accurate, flow control	expensive, cal. req.
	bubble meter	high accuracy, for cal.	atm. pressure, low flows
fuel (liquid)	load cell/timer	electrical readout, accurate, no cal.	
	turbine meter	electrical readout	cal. req.
	rotameter	flexible, inexpensive	cal. req.
	sight gauge	simple, no cal., inexpensive	manual operation
coolant, suppres-sant	turbine meter	electrical readout	more expensive
	rotameter	flexible, fail-safe	
	bucket/stop watch	inexpensive	time average

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Resolution & Uncertainty of Traditional Flow Meters

Spatial resolution: none, integrated across area

Time response: multiple seconds and slower

Uncertainty in flow:

5 % to 10 % (typical); < 5 % with care

Measurement issues: time response (transient operation only; e.g., flow of suppressant in pipe)

Exhaust duct flows

Bi-directional pitot probe:

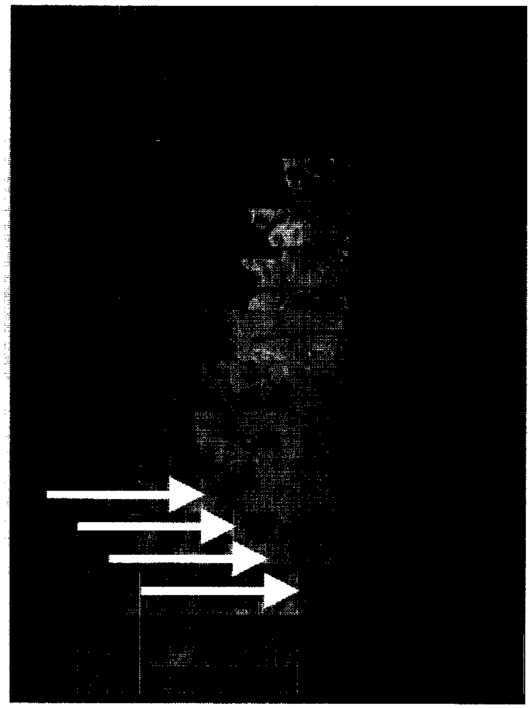
- measures ΔP upstream vs. downstream
- relates point value to cross-stream average velocity
- 0.1 to 1 s response time

Accuracy limited by:

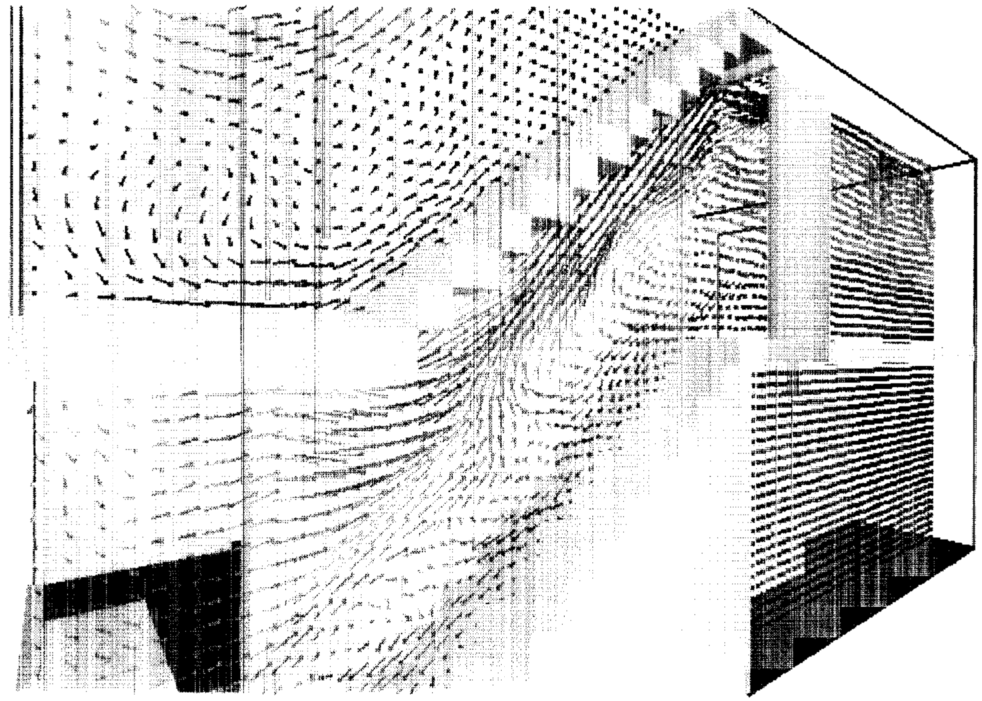
- uncertainties in local properties
- shape of velocity profile

Estimated relative std. uncertainty in flow: > 5 %

Buoyancy-induced velocity measurements for model validation



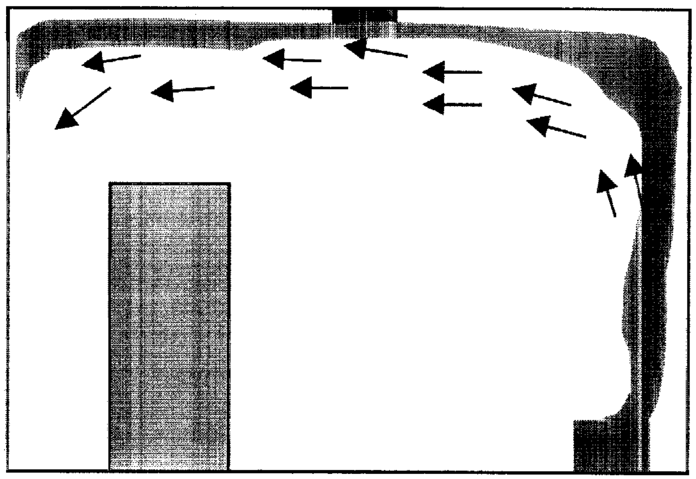
Door flows

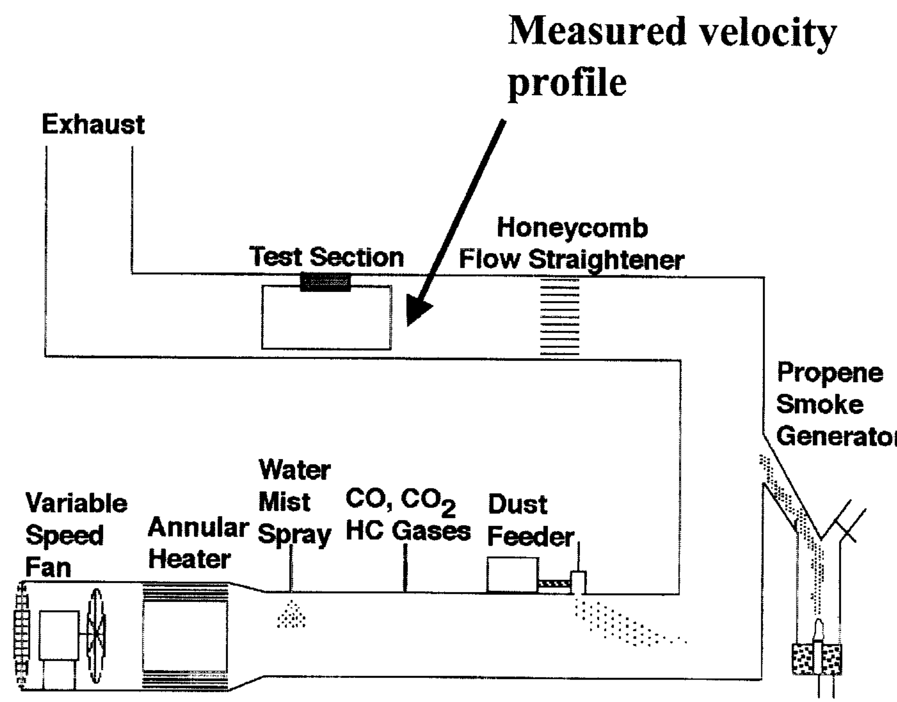


Stair flow simulation

Smoke plume & fire detector flows

Full-scale detector testing



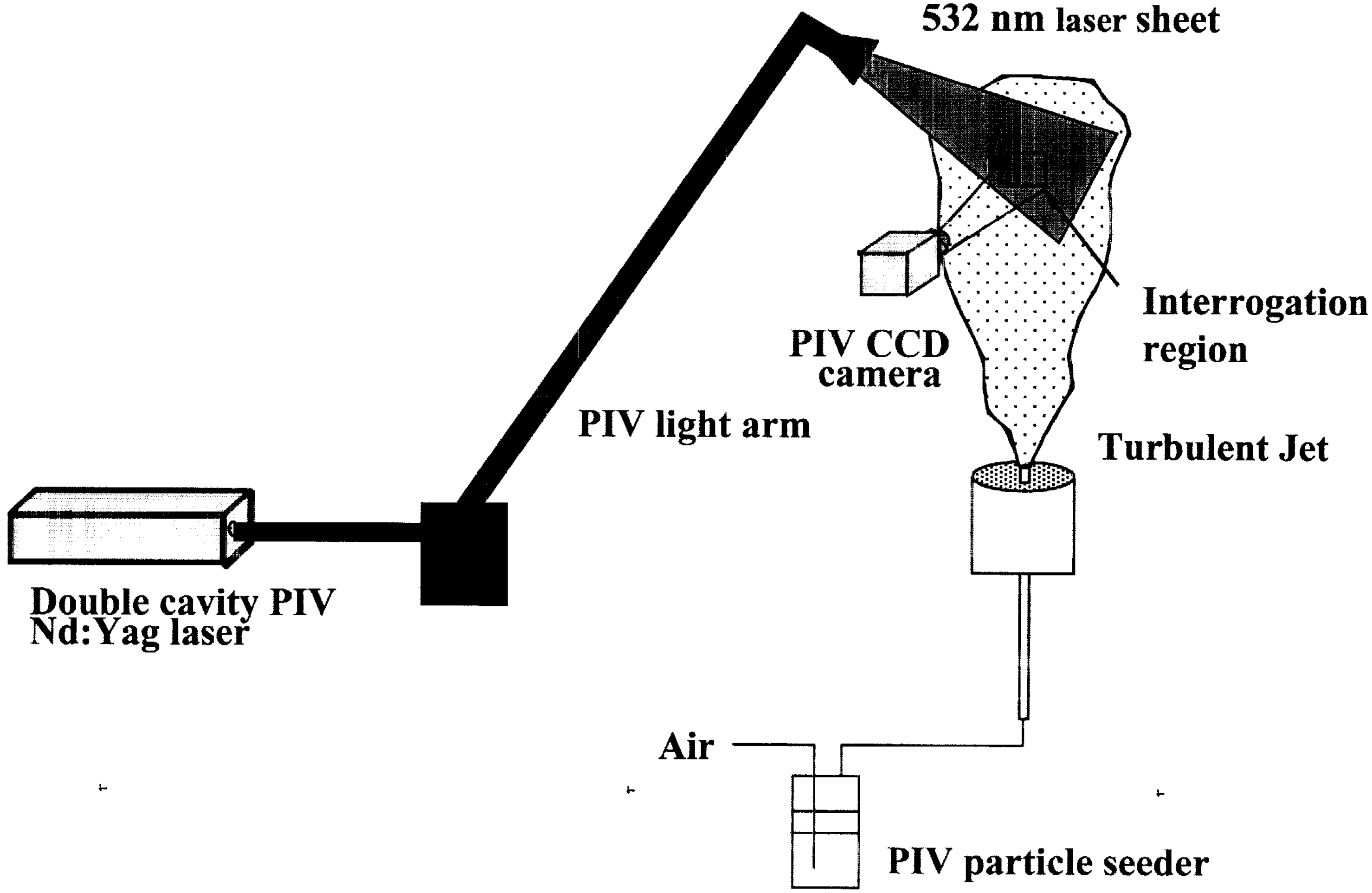


Fire-emulator/detector evaluator

Unconfined gas flow measurement methods

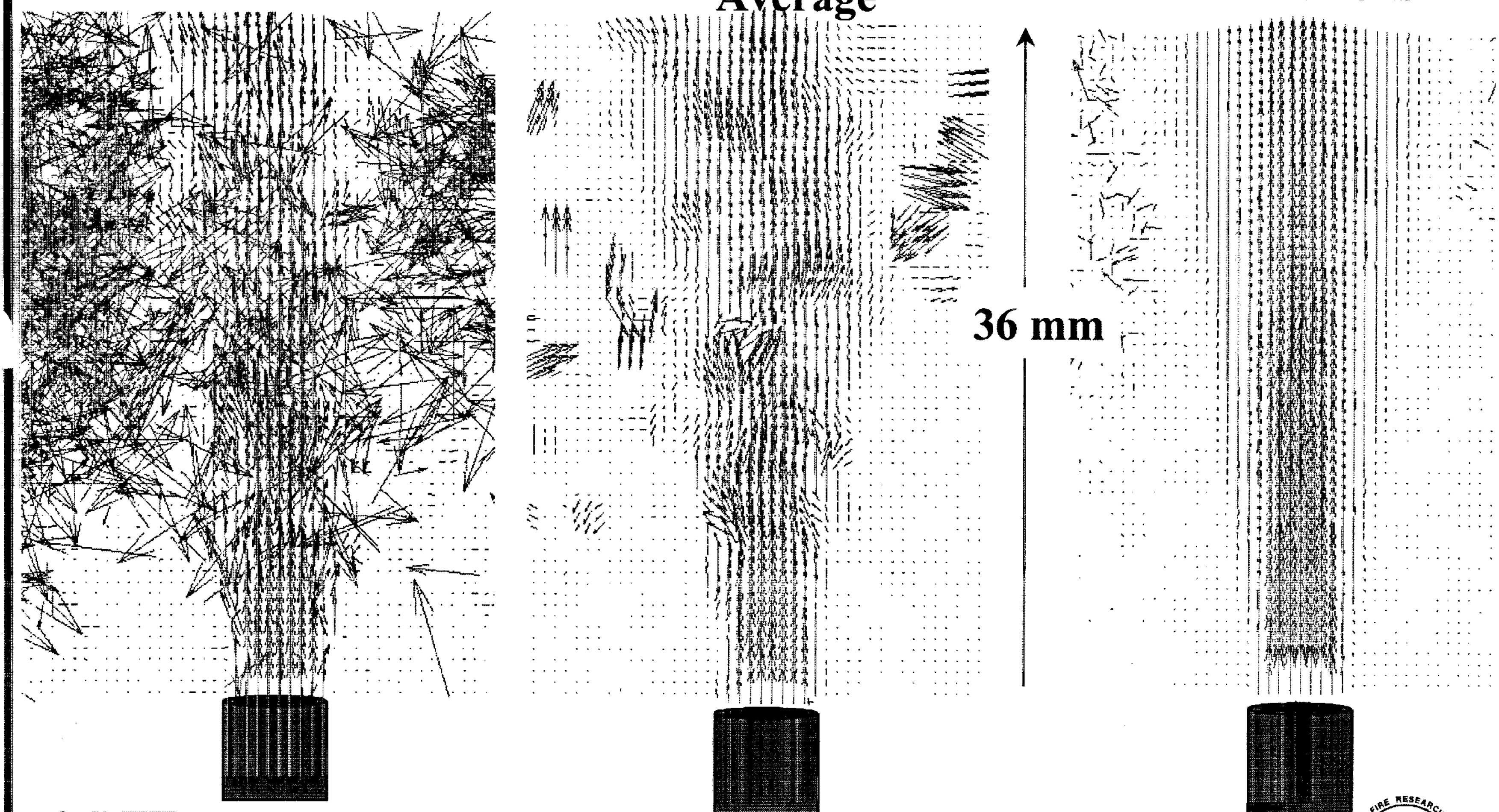
PARAMETER	DEVICE	OPERATING PRINCIPLE
single velocity component	bi-directional probe	ΔP
	pitot tube	ΔP
	hot-wire anemometer	ΔT
	laser-Doppler anemometer (LDA)	scattered light
speed + direction	wind anemometer	aerodynamic forces
2-D velocity	cross-wire anemometer	ΔT
	2-D LDA	scattered light
	phase-Doppler particle analyzer (PDPA)	scattered light
	particle imaging velocimeter (PIV)	scattered light
2-D flow	laser sheet visualization	scattered light
3-D velocity	triple-wire anemometer	ΔT
	3-D LDA	scattered light

PIV experimental setup



PIV turbulent jet velocity vectors

Raw Vectors | **Validated, 3 x 3 Spatial Average** | **Average over 50 Realizations**



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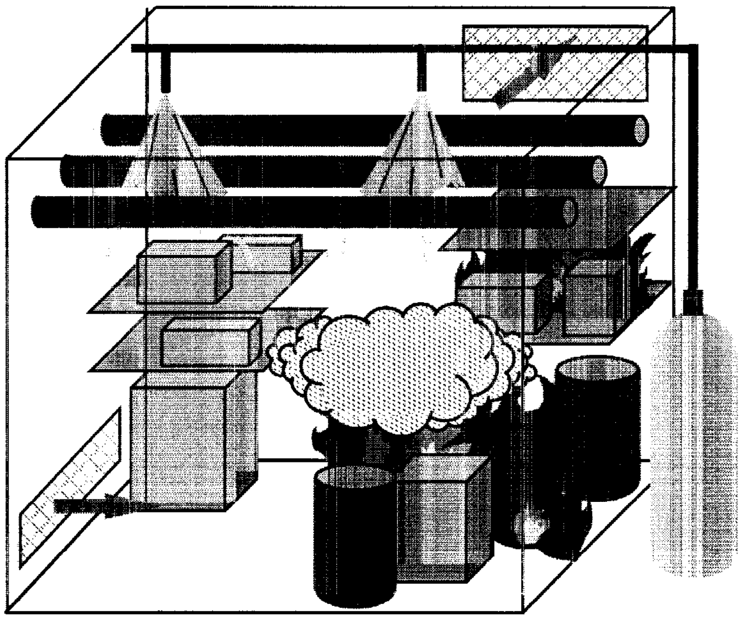
Resolution & Uncertainty of Velocity Measurements

METHOD	AREA	SPATIAL RESOLUTION	TIME RESPONSE	TYPICAL UNCERT.
hot wire probe	point	.1 to 1 mm	< 1 ms	< 2 %
LDA	point	.1 to 1 mm	1 ms to 10 s	< 4 %
pressure probe	point	1 to 10 mm	.1 to 1 s	< 10 %
wind anemometer	point	50 mm	5 s	< 20 %
PIV	1 x 1 cm to .3 x .3 m	.5 to 1 mm	1/30 s	< 5 %
particle tracking	10 x 10 cm to 1 x 1 m	1 to 5 mm	10 ms to 1 s	< 10 %

Droplet & spray flows



Halon replacement discharges

Sprinkler sprays

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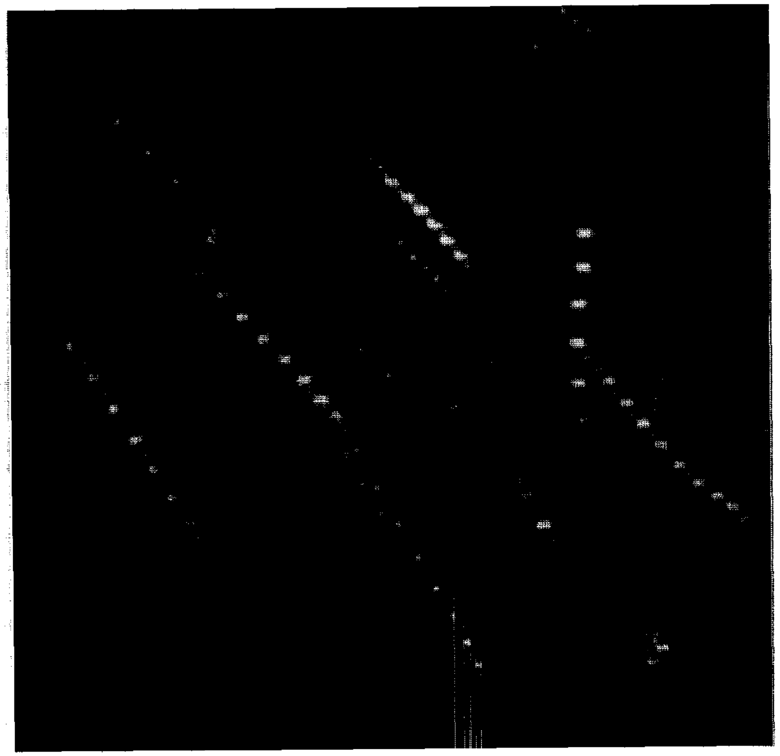
Droplet, particle flow measurement

- Buckets on floor (flow averaged over 10s of seconds and 10s of cm^2) $
- High speed movies/videos (2-D projection of flow, non-quantitative, insightful) $
- LDA (1, 2 or 3 velocity components at point) $$
- PDPA (LDA plus size) $$$
- PIV (2-D velocity vectors over area) $$$
- Particle Tracking (2-D velocity over area) $$

Laser sheet particle tracking



- Field model validation
- Sprinkler drop size and velocity
- Entrained air flow velocity
- Fire induced flows
- Non-intrusive
- 2-Dimensional plane
- High spatial resolution
- Method demonstrated at 0.25 m x 0.25 m
- Development of ability to measure 1 m by 1 m area

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Summary

Traditional methods are adequate if good engineering practice followed:

- use appropriate range (magnitude, environ.)
- calibrate
- apply realistic uncertainties

Optical methods have significant limitations:

- time response vs. velocity vs. seed particle number density (LDA and PDPA)
- particle size and shape (gas vs. droplet velocity)
- area vs. particle number, size and $ (PIV)

Flow measurement challenges

1. Air flow through openings in fire room:
   total area simultaneously
   resolved to 10 cm^2
   < 1 s time response
   2 components of velocity

2. Air entrainment into fire (same requirements)

3. Near-field in plume (same requirements)

4. Transient discharge of flashing suppressant

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Focus research on:

- Developing/optimizing particle seeding
- Increasing area coverage
- Hardening optical methods and streamlining operation
- Developing appropriate controlled experiments to validate sub-models for simulations

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